

## **ONR Code 32 {Special Award in Ocean Acoustics}**

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### **LONG-TERM GOALS**

Understand ocean processes and their relationship to acoustic propagation in the ocean.

### **OBJECTIVES**

Use ocean statistical models to predict the statistics of the phase, the (2<sup>nd</sup>, 4<sup>th</sup>, and higher) moments of the intensity, and the probability distributions of propagating sound waves in the ocean.

### **APPROACH**

Utilize data from earlier experiments to achieve this objective.

### **WORK COMPLETED**

1. A paper that discusses the three acoustic experiments (discussed below) and what we have learned to date about ocean acoustic wave propagation in random media, WPRM, in the historical context has been published. [1]
2. The data sets from 4 of my previous experiments have been converted from older formats to files that are readable in my current Matlab scientific programming system.
3. Three programs have been written, to re-analyze the data sets from the fourth experiment, and software to resolve the data in depth to the finest resolution possible is in the final stages of completion.
4. Some of the software to read the acoustic transmission experiment data has been updated to allow the re-processing of those data sets.

### **RESULTS AND DISCUSSION**

This research is conducted within the context of parts 2 and 3 of my FY 14-15 ONR proposal. Three of the four acoustic transmission experiments, where complete 3D plus time oceanographic data and simultaneous acoustic transmission data are available over a wide range of acoustic frequencies, have never been repeated. Two were carried out in the open ocean, and the third in the Arctic. In the first two the internal wave field was saturated. While the ocean model is not described accurately by the Garrett and Munk formulation, the 3D plus time model is very well known from our oceanographic

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data. This model, derived from those oceanographic data sets, provides a representation of the phase space that is unique in capturing the space and time processes. Also, the second acoustic transmission experiment utilized both broad and narrow band signals at four frequencies from 2 to 13 kHz. The third experiment, done in the Arctic at four frequencies from 2 to 16 kHz, was in a region where the internal wave and finestructure model from the AIWEX experiment (simultaneously carried out with the acoustic transmission experiment), has an energy level 50 times below that of open ocean values. This provides a rare opportunity to study ocean acoustic statistics in a weak scattering environment. (A repeat of this experiment for current Arctic conditions would allow study of the evolution of its acoustic transmission properties.) The third acoustic experiment also has the advantage of having data taken continuously over 150 meters in the vertical.

I have begun work to re-analyze the results from these experiments and publish the results in the context of our more recent understanding of ocean acoustic statistics. This analysis will require the use of the complex MDMF software (discussed in item 2 of my proposal). The data sets (discussed in item 3 of my proposal), are now in Matlab format on my current computer system and properly backed up.

The fourth experiment is a study of ocean mixing where one can observe directly the separation of internal wave and finestructure (or “spice”) processes, which is relevant to the effects on ocean acoustic transmission through the ubiquitous layers found in the ocean. The processing software (e.g. the complex MDMF capability), and some of the data handling software has been updated to work with my current computer operating system.

Realizing the full potential of these experiments, via proper storage, analysis, and publishing is the focus of my research efforts. Though this effort has required me to work far more than the time allotted under my FY 14-15 proposal, I believe it to be essential for documenting the progress made over the last 40 years., so that these very important data sets are properly retained and reported in the literature.

## **IMPACT/APPLICATIONS**

All of this work is relevant to our understanding of the relationship between ocean deterministic and statistical processes and sound propagation. The frequency range of these studies is from 2 to 16 kHz, and the ocean scales studied range from centimeters to 20 km with time scales from  $10^{-1}$ s to greater than  $10^6$  s . The methodologies used have application to signal processing in that a thorough understanding of the statistical fluctuations of signals is essential to the utilization of this understanding in signal processing algorithms.

## **TRANSITIONS**

My research has for many years involved the study of ocean sound velocity statistics and their relationship to ocean acoustics in the wave propagation in random media context. Understanding the moments of the phase and amplitude and the probability distributions of the intensity of the random acoustic signals provides the basis for developing Navy systems. This more fundamental understanding is applicable to the system oriented requirements of ONR in that it represents modeling of the ocean acoustic statistical environment, as well as the more deterministic one.

## **RELATED PROJECTS**

I plan to work with Frank Henyey on the results obtained in the re-analysis of the first three experiments, and with Eric D'Asaro (Lateral Mixing DRI Project) on the implications of the fourth experiment to the details of the layers found in the sound velocity structure in the ocean.

## **PUBLICATIONS**

1. “50 Years Studying Ocean Acoustic WPRM” by Terry Ewart, Published in the Proceedings of the ECUA12 Conference on Ocean Acoustics, Edinburgh Scotland. (Invited Keynote address), 2013 .